PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : F04D 29/04, 17/12

A1

(11) International Publication Number: WO 91/17361

(43) International Publication Date: 14 November 1991 (14.11.91)

(21) International Application Number: PCT/FI91/00122

(22) International Filing Date: 26 April 1991 (26.04.91)

(30) Priority data:
902308 8 May 1990 (08.05.90) FI

(71) Applicant *(for all designated States except US)*: OY HIGH SPEED TECH LTD. [FI/FI]; Box 306, SF-33101 Tampere (FI).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : LARJOLA, Jaakko [FI/FI]; Ravunkatu 4, SF-53850 Lappeenranta (FI). BACKMAN, Jari [FI/FI]; Saikkolantie 5, SF-53420 Lappeenranta (FI). LINDGREN, Olli [FI/FI]; Mannerheimintie 58 C 59, SF-00260 Helsinki (FI). PAAVOSEPPÄ, Mikko [FI/FI]; Kaivotie, SF-54230 Nuijamaa (FI).

(74) Agent: KAHILAINEN, Hannu; Tampereen Patenttitoimisto Oy, Kanslerinkatu 6, SF-33720 Tampere (FI).

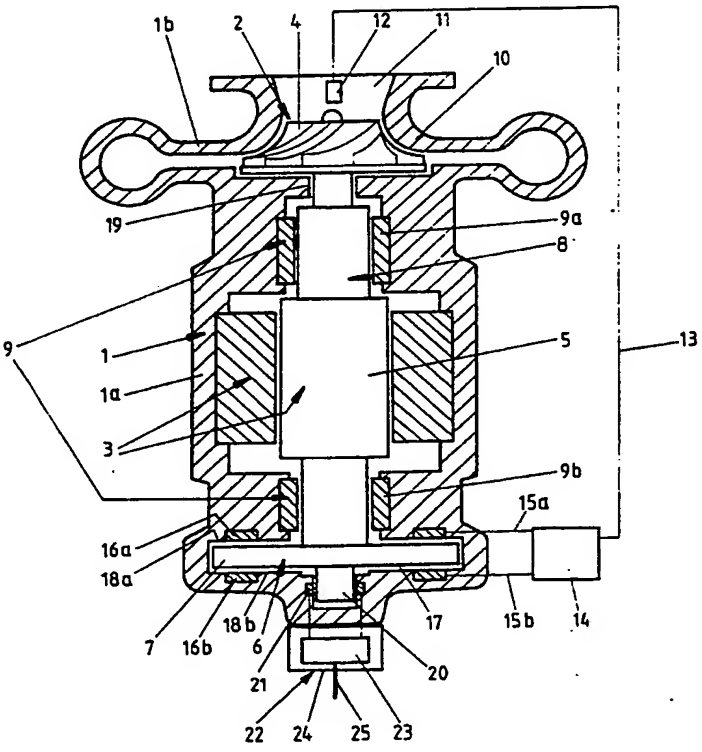
(81) Designated States: AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent), SU, US.

Published
With international search report.

(54) Title: COMPRESSOR HAVING MAGNETIC BEARING ASSEMBLY

(57) Abstract

The invention relates to a compressor, comprising an aggregate consisting of an electric motor (3), journalled inside a body (1) and serving as a compressor power unit, and of at least a single-step compressor unit (2). The compressor includes rotating components (4, 5, 7, 8) which are adapted to rotate concentrically. The journalling of such rotating compressor components in radial direction is essentially effected by means of a gas bearing assembly (9). The axially directed journalling of the compressor is effected by means of a magnet bearing assembly (6), which is adapted to receive its control from a means (11) measuring the axial position of the rotating compressor components. The type of compressor is a so-called high-speed compressor, whereby its speed of rotation is selected to be at least 2 x 10^4 rpm.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MN	Mongolia
BE	Belgium	GA	Gabon	MR	Mauritania
BF	Burkina Faso	GB	United Kingdom	MW	Malawi
BG	Bulgaria	GN	Guinea	NL	Netherlands
BJ	Benin	GR	Greece	NO	Norway
BR	Brazil	HU	Hungary	PL	Poland
CA	Canada	IT	Italy	RO	Romania
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland			SN	Senegal
CI	Côte d'Ivoire	KR	Republic of Korea	SU	Soviet Union
CM	Cameroon	LI	Liechtenstein	TD	Chad
CS	Czechoslovakia	LK	Sri Lanka	TG	Togo
DE	Germany	LU	Luxembourg	US	United States of America
DK	Denmark	MC	Monaco		

Compressor having magnetic bearing assembly.

The present invention relates to a compressor, comprising a body as well as an aggregate consisting of an electric motor journalled inside the body and serving as a compressor power unit and of at least a single-step compressor unit, the rotating components of said compressor being adapted to rotate concentrically and the journalling of the rotating compressor components in radial direction being essentially effected by means of a gas bearing assembly.

A blower unit as described above is disclosed e.g. in the publication US 3 933 416. However, the cited publication discloses the use of a motor operating on low speeds of rotation and intended particularly for pumping corrosive gases.

In several industrial processes, e.g. in pharmaceutical industry, food industry, textile industry etc., it is of extreme importance to obtain oilless compressed air. In so-called oilless compressors, traditionally designed for such purposes, the access of oil into compressed air is prevented by means of sealings or a like method but, in principle, an oil leak is always a possibility and, thus, the use of this type of constructions always involves considerable risks. In principle, the blower unit set forth in the publication US 3,933,416 operates without oil lubrication but its construction is unfavourable in applications which require a compact compressor and at the same time reasonable outputs. Such requirements lead to high rotating speeds for the rotating compressor components. In particular, a blower unit as set forth in US publication 3 933 416 is not capable of handling axial stresses in such applications.

An object of this invention is to introduce a compressor which is capable of eliminating the above drawbacks in applications that require a compact, high-capacity and reliable compressor. In order to achieve this object, a compressor of the invention is primarily characterized in that the axial journalling is carried out by means of a magnet bearing assembly, adapted to receive its control from an element measuring the axial position of the rotating compressor components, and that the effective rotating speed of the compressor is selected to be at least 2×10^4 rpm. Thus, a compressor designed as described above operates entirely on oilless bearing assemblies, so an oil leak into the compressed air to be pumped is impossible. Hence, a compressor of the invention can be used safely in industrial processes which are sensitive to oil. On the other hand, the gas and magnet bearing assemblies have constructionally a long service life. Since it is further possible to construct a compressor so as to be only fitted with non-contact sealings, such compressor is as good as free of maintenance in clean conditions. In most applications, a gas bearing assembly is very simple of set up, nor does it require adjustments during operation. An axially operating dynamic magnet bearing assembly can be set up by means of several different constructive methods. A magnet bearing assembly requires an element measuring the axial position of the rotating components of a compressor and a control circuit for providing dynamic qualities, since the positional stability of the rotor wheel of a high-speed compressor is subject to strict requirements, particularly due to small clearances. Nevertheless, such a control circuit is relatively simple to design. If the electric motor employed is a permanently magnetized electric motor, which is quite obviously the most preferred option, the compressor can be provided with a high efficiency and rotor dissipations are extremely low, so the compressor

cooling can be readily carried out. Typically, a compressor of the invention can be given the following ratings, capacity: 10-500 kW, speed of rotation 2 x 10^4 - 10^5 rpm, and trouble-free service life in reasonable conditions appr. 10 years.

Some preferred embodiments for a compressor of the invention are set forth in the annexed non-independent claims.

The invention will be described in more detail in the following specification with reference made to the accompanying drawing, which shows in a cross-section one embodiment for a compressor of the invention.

A compressor of the invention comprises as its main components a body 1, a compressor unit 2 and an electric motor 3. The rotating components of a compressor, i.e. a rotor wheel 4 included in compressor unit 2, a rotor 5 included in electric motor 3, and a radial plate 7 included in a magnet bearing assembly 6, are all mounted on a main shaft 8 to rotated concentrically around the centre axis of said main shaft 8 upon a bearing assembly included in body 1. Said bearing assembly comprises first of all a radial gas bearing array 9 whose component 9a and 9b are mounted on body 1 on either side of electric motor 3 in the longitudinal direction of main shaft 8. Secondly, said bearing assembly includes e.g. a magnet bearing array 6 which in the illustrated embodiment is mounted on the end of body 1 furthest away from compressor unit 2. Said body 1 includes integral body sections 1a and 1b for an electric motor and a compressor unit.

The compressor unit 2 includes a stator section 10 whose intake duct 11 is fitted with a means 12 measuring the position of the rotating compressor components, especially that of rotor wheel 4, said means being electrically 13 connected with a control circuit 14 for controlling the operation of magnet bearing assembly 6. Power supply is arranged from control circuit 14 along conductors 15a, 15b to means for the regulation of field strength, particularly to electromagnets 16a, 16b. Electromagnets 16a, 16b are located in a chamber 17 surrounding said main shaft 8 and extending transversely, preferably perpendicularly, to its longitudinal direction, and fastened to its opposite, radially-directed walls 18a, 18b. Said chamber 17 is provided with a radial plate 7 mounted on main shaft 8, and particularly on rotor wheel 4. As described above, a compressor can be provided with a bilateral dynamic magnet bearing assembly which controls the axial position of main shaft 8 by means of control circuit 14 on the basis of measuring data supplied by said measuring means 12 associated with compressor unit 2.

On the opposite side relative to intake duct 11 of rotor wheel 4 said body is provided with a non-contact sealing 19 between the rotating compressor components and body 1. By way of reference, the drawing further shows an extension 20 for main shaft 8 as well as measuring elements 21, located in a recess included in body 1 and intended particularly for an angle of position, said elements being intended for a possible self-commutating circuit. Such circuit is particularly useful whenever said electric motor 3 comprises a brushless permanently magnetized direct-current machine. The drawing shows diagrammatically a current-supply system 22 applicable in this alternative electric motor design, which system can be mounted on the end of body 1. Elements 21 are connected to a

control unit 23 which is fitted in a housing or a like 24. The supply of power occurs along a cable 25 to the control unit which includes an alternating transformer as mentioned above.

A compressor of the invention can be provided with several types of electric motors as well as several means of controlling such electric motors. The selection of a motor type can be effected particularly according to the requirements set by the intended application of the compressor. As for the type of electric motor, said motor can be either a short-circuit machine, a permanently magnetized synchronous machine or a brushless permanently magnetized direct-current machine. Every electric motor of this type is provided with a similar stator. Thus, in terms of manufacturing technique, the construction will be preferable since the compressors applicable to various purposes are provided with identical bodies and stators. A permanently magnetized motor has a high efficientcy and rotor dissipations are negligible, whereby the cooling is easily arranged. On the other hand, the rotor of a short-circuit machine is mechanically simple but, at least in certain applications, it is hampered by more significant dissipations. Thus, a short-circuit machine is useful in applications where cooling is easily arranged. The supply of power in both a permanently magnetized synchronous machine and in a short-circuit machine can be effected by means of a frequency transformer. The supply of power in a brushless permanently magnetized direct-current machine is effected by means of an inverter, whose control can be carried out by measuring the angle of position of the magnetic axis of the rotor. Such control is particularly suitable for the supply of high-speed electric machines as it can be effected in a simple manner if compared to conventional frequency transformers. In addition, an inverter and a

control unit required for measuring the angle of position of the magnetic axis of a rotor are compact in size and, hence, can be permanently fixed to the body of a compressor.

A compressor of the invention can be designed in many different ways, particularly in terms of bearing assemblies. Thus, the magnet bearing assembly may consist of two sections, whereby a first electromagnet e.g. 16a is fitted e.g. in a chamber provided between a gas bearing 9a and a non-contact sealing 19, said chamber being provided with a plate corresponding to radial plate 7, and whereby a second electromagnet 16b and other constructive components shown in the drawing are identical to those shown in the drawing for magnet bearing assembly 6. It is of course obvious that the components of a two-component or multi-component magnet bearing assembly 6 can both, either one or some comprise a bilateral construction.

Claims

1. A compressor, comprising:

- a body (1), as well as
- an aggregate consisting of an electric motor (3), journalled inside said body (1) and serving as a compressor power unit, and of at least a single step compressor unit (2), whereby
- rotating compressor components (4, 5, 7, 8) are adapted to rotate concentrically, and whereby
- the journalling of such rotating compressor components in radial direction is essentially effected by means of a gas bearing assembly (9),

characterized in that the axially directed journalling is effected by means of a magnet bearing assembly (6), which is adapted to receive its control from a means (12) measuring the axial position of the rotating compressor components, and that the effective speed of rotation of the compressor is selected to be at least 2×10^4 rpm.

2. A compressor as set forth in claim 1, **characterized** in that said means (12) measuring the axial position of rotating compressor components (4, 5, 7, 8) is mounted in connection with compressor unit (2).

3. A compressor as set forth in claim 2, **characterized** in that said means (12) measuring the axial position of rotating compressor components (4, 5, 7, 8) is mounted adjacent to a compressor unit rotor wheel (4) in an intake duct (11).

4. A compressor as set forth in any of claims 1-3, **characterized** in that said means measuring the axial position of rotating compressor components (4, 5, 7,

8) is connected with a control circuit (14) for regulating the field strength of magnet bearing assembly (6).

5. A compressor as set forth in any of claims 1-4, **characterized** in that said magnet bearing assembly (6) is bilateral.

6. A compressor as set forth in any of claims 1-5, **characterized** in that said magnet bearing assembly (6) includes at least one chamber (17) or a like, designed in body (1) and extending transversely, preferably perpendicularly, to the axial direction of the rotating compressor components, at least one of the radially directed walls (18a, 18b) of said chamber being fitted with elements for producing a magnetic field (16a, 16b), and that said at least one chamber (17) is provided with a radial plate (7) or a like fastened to the rotating compressor components.

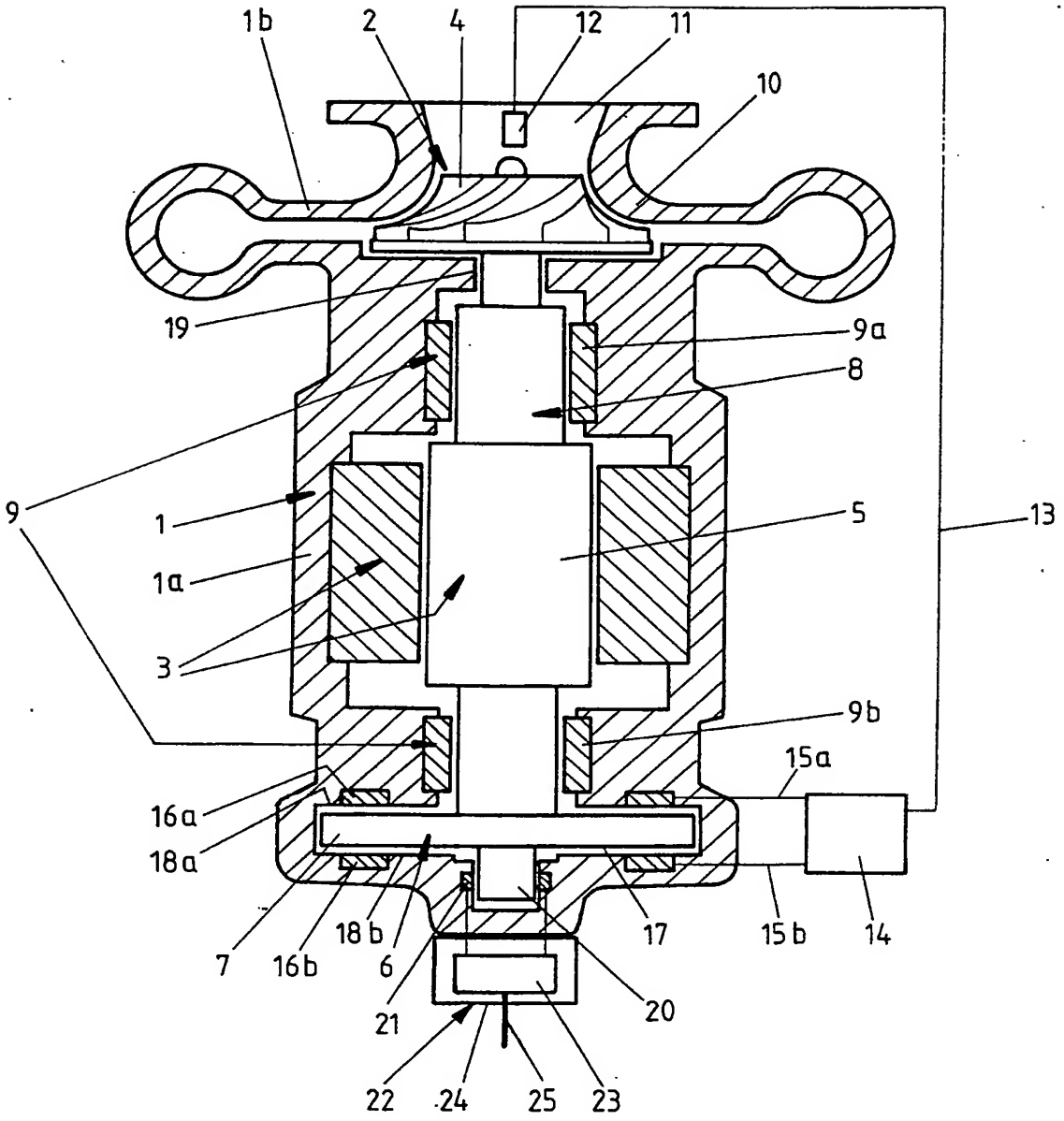
7. A compressor as set forth in any of claims 1-6, **characterized** in that at least a part of magnet bearing assembly (6) is positioned in a manner that said electric motor (3) is located in the longitudinal direction of the compressor between compressor unit (2) and a part of magnet bearing assembly (6) or the above-mentioned part thereof.

8. A compressor as set forth in claim 1, **characterized** in that the type of electric motor (3) is a permanently magnetized synchronous motor or a short-circuit machine, whose power supply is effected by means of a frequency transformer.

9. A compressor as set forth in claim 1, **characterized** in that the type of electric motor (3) is a brushless direct-current machine, whose power supply is effected

by means of an inverter having its control based on measuring the angle of position of rotating compressor components (4, 5, 7, 8).

10. A compressor as set forth in claim 1, **characterized** in that on the side of the body furthest away from said intake duct (11) of rotor wheel (4), said body (1) is fitted with a non-contact sealing (19) between rotating compressor components (4, 5, 7, 8) and body (1).


1b
2
4
12
11
10
19
9a
8
9
1
5
13
1a
3
9b
15a
16a
18a
7
16b
18b
6
17
15b
14
21
20
22
24
25
23

INTERNATIONAL SEARCH REPORT

International Application No PCT/FI 91/00122

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: F 04 D 29/04, 17/12

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	F 04 D

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
Y	EP, A2, 0355796 (EBARA CORPORATION) 28 February 1990, see figures 1-2b; claims 1-5 --	1-10
Y	EP, A2, 0361844 (NOVA CORPORATION OF ALBERTA) 4 April 1990, see figures 1-2; claims 1-8 --	1-10
Y	US, A, 3933416 (DONELIAN) 20 January 1976, see column 3, line 54 - line 57; figure 1 --	1-10
Y	US, A, 4523896 (LHENRY ET AL) 18 June 1985, see figures 1-4 description --	1-10

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
22nd August 1991	1991 -08- 29
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	Lena Johansson

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 4969803 (TURANSKYJ) 13 November 1990, see the whole document --	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/FI 91/00122

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the Swedish Patent Office EDP file on 91-06-27
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A2- 0355796	90-02-28	JP-A-	2055896	90-02-26
EP-A2- 0361844	90-04-04	AU-D-	4236689	90-04-05
		US-A-	4993917	91-02-19
US-A- 3933416	76-01-20	NONE		
US-A- 4523896	85-06-18	DE-A-C-	3319112	83-12-08
		FR-A-B-	2528127	83-12-09
		GB-A-B-	2121479	83-12-21
		JP-A-	59068595	84-04-18
US-A- 4969803	90-11-13	DE-C-	3729486	88-12-15
		EP-A-	0305700	89-03-08
		JP-A-	1080799	89-03-27